#319
In Psychological Review, 1976, 83, 318-322.

Models of Sentence Verification and Linguistic Compreh

Patricia A. Carpenter and Marcel Adam Just
Carnegie-Mellon University

This paper discusses a number of issues that bear on the scientific useful of sentence verification models. These models explain how information fro sentence is compared to its referent. The comparison processes are a form integrative processes that commonly occur in comprehending a sentence. verification models have shown that the representation of a sentence is sens to the context in which it occurs. Unlike alternative theoretical approac verification models do deal with this context sensitivity. On the other h some properties of the representation and the processing are invariant ac different contexts. An analysis of these invariants contributes substantially our understanding of comprehension and cognitive processes.

C+P 319

Psychological Review
1976, Vol. 83, No. 4, 318–322

Models of Sentence Verification and Linguistic Comprehension

Patricia A. Carpenter and Marcel Adam Just
Carnegie-Mellon University

This paper discusses a number of issues that bear on the scientific usefulness of sentence verification models. These models explain how information from a sentence is compared to its referent. The comparison processes are a form of integrative processes that commonly occur in comprehending a sentence. The verification models have shown that the representation of a sentence is sensitive to the context in which it occurs. Unlike alternative theoretical approaches, verification models do deal with this context sensitivity. On the other hand, some properties of the representation and the processing are invariant across different contexts. An analysis of these invariants contributes substantially to our understanding of comprehension and cognitive processes.

In this paper, we contrast an information-processing approach to sentence comprehension with another approach that is derived from the discipline of linguistics. In particular, we examine models of sentence verification in light of some criticisms of Tanenhaus, Carroll, and Bever (1976). One criticism is that sentence verification models do not concern themselves with comprehension processes but rather with processes that occur after a sentence is comprehended. A second criticism is that the models make use of too much flexibility in postulating sentence representations. A third criticism is that verification models are uninteresting because they are task-specific. While Tanenhaus et al. (1976) do not explicitly formulate an alternative position, these criticisms are based largely on the assumptions and goals associated with a linguistics-based approach. The present paper addresses three main areas of disagreement between the linguistics-based approach and an information-processing approach: (a) the nature of comprehension processes, (b) the nature of a sentence representation, and (c) subject strategies. Finally, we list a number of errors in the Tanenhaus et al. (1976) paper.

Views of Comprehension

Tanenhaus et al. (1976) argue that verification models do not concern themselves with comprehension but rather with processes that occur after a sentence is comprehended. Their view assumes that deriving a structural description of a sentence, parsing, is the only process involved in comprehension. This view betrays the assumptions borrowed from linguistic theory. These assumptions led the linguistics-based approach to focus on the human internal structure that corresponds to the linguistic deep structure and the mental operations that correspond to linguistic transformations. On one hand, the assumption that mental operations correspond to linguistic transformations has been somewhat discredited (cf. Watt, 1970). On the other hand, the linguistics-based approach continues to focus on the relation between the sentence and its deep structure and the parsing process that computes this relation. This view equates parsing with comprehension, and according to Tanenhaus et al., a sentence that has been parsed has been "already understood."

An alternative view is that sentence comprehension consists of several processing activities, only one of which is parsing. In this view, sentence comprehension consists of extracting the relevant information from a sentence and, when possible, integrating that information with other semantic or procedural knowledge. In fact, the parsing process and the integrative processes may interact. The distinction between the two views of comprehension can be clarified by considering how the following paragraph might be comprehended:

> The procedure is actually quite simple. First you arrange things into different groups. Of course, one pile may be sufficient depending on how much there is to do. If you have to go somewhere else due to lack of facilities that is the next step, otherwise you are pretty well set. It is important not to overdo things. That is, it is better to do too few things at once than too many (Bransford & Johnson, 1973, p. 400).

This research has been supported in part by Grant MH-07722 from the National Institute of Mental Health.

We thank Bill Chase, Peter Dixon, Jola Jakimik, David Klahr, and Herbert Simon for their comments on earlier drafts of this article.

Requests for reprints should be sent to Patricia A. Carpenter, Department of Psychology, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213.

This paragraph was presented either with or without the title "Washing Clothes." Even though the sentences can be parsed equally well with or without the title, knowing the title affects the nature of the comprehension process. For example, subjects who knew the title rated the sentences as more comprehensible. Yet Tanenhaus et al.'s approach would claim that the sentences were "understood" similarly in the two cases, because their approach equates parsing with comprehension. But comprehension involves other processes besides parsing. The title "Washing Clothes" allows the reader to access his own knowledge of laundry procedures, and consequently he can infer the referents of the propositions, pronouns, definite descriptions, and unspecified words such as *things*. Knowing the title allows the reader not only to parse but also to relate the information in the sentence to its referent. How information from a sentence is related to its referent is the aspect of comprehension that has been the focus of sentence-verification research.

In sentence-verification tasks, subjects decide whether a sentence is a true or false description of its referent, whether the referent is a picture or information stored in semantic memory. The task requires a comparison between the information extracted from the sentence and the referential information. Verification models specify the comparison process and accurately account for the response latencies. The models also tell us something about the end-product of the parsing process, the information that is extracted from the sentence. But they focus on integrative and comparison processes, aspects of comprehension that are completely ignored by the linguistics-based approach.

Representation of Linguistic Information

The two approaches to sentence comprehension also differ in how much invariance they attribute to the internal representation of a sentence. The linguistics-based approach assumes that the internal representation, like the linguistic deep structure, is the same regardless of the extralinguistic context. Tanenhaus et al. (1976) assume the existence of an invariant, canonical representation, which they call a "linguistic deep structure representation." According to this approach, a comprehension theory should specify *the* representation of linguistic structures, and this view has led its proponents to erroneously assume an invariant representation where none existed. For example, Savin and Bever (1970), using data from a phoneme monitoring task, argued that *the* unit of speech perception was the syllable (or an even larger unit), but that it was *not* the phoneme. However, McNeill and Lindig (1973) showed that as the task is slightly altered, the phoneme, or the syllable, or the word, or even the sentence becomes *the* unit of processing, depending on the task demands. In other words, subjects' representations changed systematically with the experimental context; there was no unit of processing that was invariant over tasks. Similarly, we suggest that the representation of a sentence depends upon the context; there need be no single, canonical representation for a sentence type.

The information-processing view suggests that the process that constructs the internal representation of a sentence is sensitive to the linguistic and extralinguistic contexts. The context can influence the parsing process by determining what information is to be extracted from a sentence and how that information is to be represented. One goal of a comprehension theory, according to this viewpoint, is to specify how context interacts with the parsing process to produce the resulting representations. One possible form of interaction may be that the context specifies ahead of time what information is to be looked for in a sentence. The context may provide a frame with some variables left unspecified. The parsing of the sentence may proceed only until the unspecified information is found. The search for the relevant information may start at a relatively superficial level, and only if it were unsuccessful at that level would it proceed to deeper levels. In this way, contextual constraints might guide the parsing to shallower or deeper levels of analysis in pursuit of particular goals.

A verification task provides a context that clearly indicates what information should be extracted from the sentence. For example, to verify a sentence such as *It isn't true that the dots are red* with respect to a group of red dots or black dots, the subject must determine what color is mentioned in the sentence and whether the inner and outer clauses are affirmative or negative. If the outer clause is the affirmative *It is true that,* it can be ignored. Tanenhaus et al. object to the plausible proposal that this outer clause is not represented. Their objection notwithstanding, experience with the possible range of sentences in this task allows the subject to develop a frame for what is relevant and then extract only the relevant information from the sentences. In other comprehension situations such as reading, the topic sentence of the paragraph may provide the context or frame with respect to which each successive sentence is analyzed.

One goal of the sentence-verification research is to discover how sentences are represented in different contexts. We have taken the approach of systematically observing performance in a number of contexts, and inferring the general rules for sentence representation. Thus, we have inductively arrived at some of the rules that relate the extralinguistic context, the sentence, and the internal representation that is constructed. While the current set of rules is incomplete, the representations postulated are substantially constrained by considerations of consistency, parsimony, plausibility, and ability to account for the observed behavior. Tannenhaus et al. (1976) object to the use of the inductive process in establishing how a sentence is represented, saying that "this is a wild card: There is no theoretical principle that determines beforehand what will be selected," (p. 313). But if sentence representations are influenced by the context, an inductive process is a necessary step in building a theory of sentence comprehension. The verification paradigm helps establish the principles that relate the sentence and its representation.

Subject Strategies

People can sometimes find different ways to perform even simple tasks, and such flexibility in strategies presents a challenge to any theoretical analysis. The linguistics-based approach offers little insight into how subjects might formulate and execute different strategies.[1] Nevertheless, in many tasks there are changes in behavior that can be explained only in terms of strategy changes. These different strategies can be captured by slightly different processing models, which then must be related to each other.

One way to relate the models is to systematically study how the structure of the task environment affects various aspects of the processing strategy. The work on sentence verification offers a case study of this approach. Different models have been developed to describe performance in different tasks. Then, a more general theory describes what task conditions determine the subject's choice of strategies and what invariants persist across the different models.[2] We shall now discuss the primary task-specific strategies and some of the major invariants across sentence verification models.

There are two strategies that are used for verifying affirmative and negative sentences. The primary strategy is described in the constituent comparison model. The alternative strategy is to recode a negative sentence into an equivalent affirmative form (if one exists) before comparing it to its referent.[3] For example, *The door is not open* may be recoded into *The door is closed.* Verification models make it possible to infer when recoding occurs by examining the pattern of latencies. When a negative is not recoded, the true case is verified *slower* than the false case. When recoding does occur, a true negative is verified *faster* than a false one (see Carpenter & Just, 1975, for a validation of this test). The recoding strategy is used only under certain conditions. It is generally used only by adults, not children (Slobin, 1966). It tends to be used only if the subject is given adequate time to manipulate the sentence representation before starting the comparison operations (Carpenter, 1973; Carpenter & Just, 1975). It is invoked only after some practice in the task (Carpenter & Just, 1975). It is applied to certain kinds of negatives (e.g., *It's true that the dots aren't red*) but not to others (e.g., *It isn't true that the dots are red*). In summary, negative sentences are recoded by adult subjects if they have the experience and time to use the recoding strategy. Both the recoding and nonrecoding strategies fit into a single theory of sentence verification. By examining a variety of task conditions, it is possible to identify which particular strategy is used and what conditions invoke that strategy.

By studying verification strategies across task conditions, it is also possible to identify invariants of representation and processing. One invariant is that negative sentences are internally

---

[1] Tanenhaus et al. (1976) suggest that if after some practice in a verification task, subjects shift from one strategy to an alternative one, then the model of the first strategy is somehow disconfirmed. Clearly, the existence and emergence of a second strategy does not affect the validity of the first model.

[2] Using a single formalism as a metatheory might make more apparent the commonalities and differences of processing models for different conditions. Production systems are one example of this kind of metatheory; they can be thought of as assembly kits for constructing models for particular tasks (Newell, 1973).

[3] One might be tempted to try, as Tanenhaus et al. (1976) suggest, to study the performance during "warm up" trials, when strategies presumably are being constructed and tested. This approach is sound in principle, but constrained by the scarcity of appropriate methodologies. For example, chronometric analyses are difficult to apply. The number of observations per person is inherently small, since subjects arrive at a stable strategy after only a handful of trials. Moreover, since subjects may try several strategies during the few warm-up trials, each latency may reflect different underlying processes. This precludes averaging across observations.

represented as an affirmative core embedded in a negation marker; for example, *The dots are not red* may be represented as [NEG, (RED, DOTS)]. A negative representation takes longer to verify than the corresponding affirmative representation. It takes longer to compare a negative representation to its referent, because the referent, be it a picture or knowledge in semantic memory, is usually represented in an affirmative form. The mismatch in affirmative–negative polarity produces the extra time-consuming operations.

This characterization of the representation and processing of explicit negatives such as *not red* can also be applied to certain implicit negatives. By using the performance characteristics identified by verification models, we have shown that certain quantifiers, such as *few* and *scarcely any*, are represented and processed like explicit negatives; other superficially similar quantifiers, such as *a minority*, are processed as affirmatives (Just & Carpenter, 1971). Similarly, the implications of sentences with predicates such as *forget* or *thoughtless* have been shown to be represented and processed as negatives (Just & Clark, 1973). Also, this technique has shown that lexically marked words, such as *small* or *short*, are represented differently from negatives such as *not large* or *not tall* (Just & Carpenter, 1971). Thus, the verification models have elucidated how the pervasive linguistic structure of negation is represented and processed in a variety of verification and question-answering tasks.

A second invariant is that the comparison process is the same regardless of whether the referent of the sentence is a picture or knowledge stored in semantic memory. For example, even though *The dots are/aren't red* refers to a picture while *Seven is/isn't an odd number* refers to knowledge in semantic memory, the comparison processes and resulting latencies are accounted for by a single model. Similarly, a single model accounts for the verification of *All/some of the red figures are round* and *All/some doctors are female* (Just, 1974). Moreover, the estimated duration of the comparison operation is similar in the two cases. Thus, the models describe comparison processes in comprehension that are invariant, qualitatively and quantitatively, over referential domains. This demonstrates how important invariants can be discovered by a general theory that relates a number of more task-specific models. Thus, a certain amount of task specificity may be a necessary step in building more general theories. By contrast, the linguistics-based approach sometimes assumes cross-task invariants where they do not exist, as the research on the phoneme monitoring task has demonstrated.

Specific Rejoinders

There are a number of errors in the Tanenhaus et al. (1976) paper that may lead to misunderstanding. For example, Tanenhaus et al. claim that Carpenter and Just "report no differences for such recognized linguistically marked/unmarked pairs as *small/large*" (1976, p. 316). On the contrary, numerous studies, including research cited by Tanenhaus et al. (Just & Carpenter, 1971), report processing differences between these and other linguistically marked/unmarked terms. A second error is Tanenhaus et al.'s statement that "the ordering [of latencies] TA < FA < FN < TN obtains only when more than one picture may falsify each sentence" (1976, p. 313). A number of studies with only one falsifying picture show this pattern (summarized in Carpenter & Just, 1975, Table 4). A third error is that Clark and Chase (1972) do not claim, as Tanenhaus et al. say, that "sentences and pictures *can* be compared *only* if there is a common 'language'" (1976, p. 316, Tanenhaus et al.'s italics). Rather, Clark and Chase show (1972, pp. 498–499) that the verification results are inconsistent with the simple kinds of mapping models proposed by Tanenhaus et al., and so the common format assumption is supported on empirical, not logical, grounds. A fourth error is Tanenhaus et al.'s claim that the Clark and Chase model can distinguish between false affirmatives and false negatives only because of the asymmetry in the representation of affirmatives and negatives. But in fact, the model distinguishes these two conditions on the basis of which constituents of the sentence and picture representations mismatch. Moreover, the constituent comparison model postulates no representational asymmetry between simple affirmatives and negatives (Carpenter & Just, 1975, pp. 49–50) and accurately accounts for the verification latencies.

Conclusions

Models of sentence verification have been successful in explaining the processes by which information from a sentence is compared to its referent. The models have directly led to the clarification of a range of related comprehension issues, such as the representation and interrogation of presuppositions and implications (Just & Clark, 1973); the relation between sentence comprehension and later recall (Just & Carpenter, in press); the processing of quantified sentences (Just, 1974); the processing of lexical marking (Clark & Chase, 1972); and the development of verification abilities in children (Lazerson &

Irving, in press). Another important aspect of the sentence verification models is that their underlying operations (such as comparing two items or retrieving the next item in a list) are not specific to language processing. These operations are also involved in other cognitive tasks such as memory scanning and so may be of a more general nature. Thus, verification models have helped to integrate the study of comprehension with other areas of cognition.

REFERENCES

Bransford, J. D., & Johnson, M. K. Considerations of some problems of comprehension. In W. G. Chase (Ed.), *Visual information processing*. New York: Academic Press, 1973.

Carpenter, P. A. Extracting information from counterfactual clauses. *Journal of Verbal Learning and Verbal Behavior*, 1973, *12*, 512–521.

Carpenter, P. A., & Just, M. A. Sentence comprehension: A psycholinguistic processing model of verification. *Psychological Review*, 1975, *82*, 45–73.

Clark, H. H., & Chase, W. G. On the process of comparing sentences against pictures. *Cognitive Psychology*, 1972, *3*, 472–517.

Just, M. A. Comprehending quantified sentences: The relation between sentence–picture and semantic memory verification. *Cognitive Psychology*, 1974, *6*, 216–236.

Just, M. A., & Carpenter, P. A. Comprehension of negation with quantification. *Journal of Verbal Learning and Verbal Behavior*, 1971, *10*, 244–253.

Just, M. A., & Carpenter, P. A. The relation between comprehending and remembering some complex sentences. *Memory & Cognition*, in press.

Just, M. A., & Clark, H. H. Drawing inferences from the presuppositions and implications of affirmative and negative sentences. *Journal of Verbal Learning and Verbal Behavior*, 1973, *12*, 21–31.

Lazerson, B. H., & Irving, E. Semantic memory verification of binary statements by subjects at three academic levels. *Journal of Experimental Child Psychology*, in press.

McNeill, D., & Lindig, K. The perceptual reality of phonemes, syllables, words, and sentences. *Journal of Verbal Learning and Verbal Behavior*, 1973, *12*, 419–430.

Newell, A. Production systems: Models of control structures. In W. G. Chase (Ed.), *Visual information processing*. New York: Academic Press, 1973.

Savin, H. B., & Bever, T. G. The non-perceptual reality of the phoneme. *Journal of Verbal Learning and Verbal Behavior*, 1970, *9*, 295–302.

Slobin, D. I. Grammatical transformations in childhood and adulthood. *Journal of Verbal Learning and Verbal Behavior*, 1966, *5*, 219–227.

Tanenhaus, M. K., Carroll, J. M., & Bever, T. G. Sentence–picture verification models as theories of sentence comprehension: A critique of Carpenter and Just. *Psychological Review*, 1976, *83*, 310–317.

Watt, W. C. On two hypotheses concerning psycholinguistics. In J. R. Hayes (Ed.), *Cognition and the development of language*. New York: Wiley, 1970.

(Received February 4, 1976)